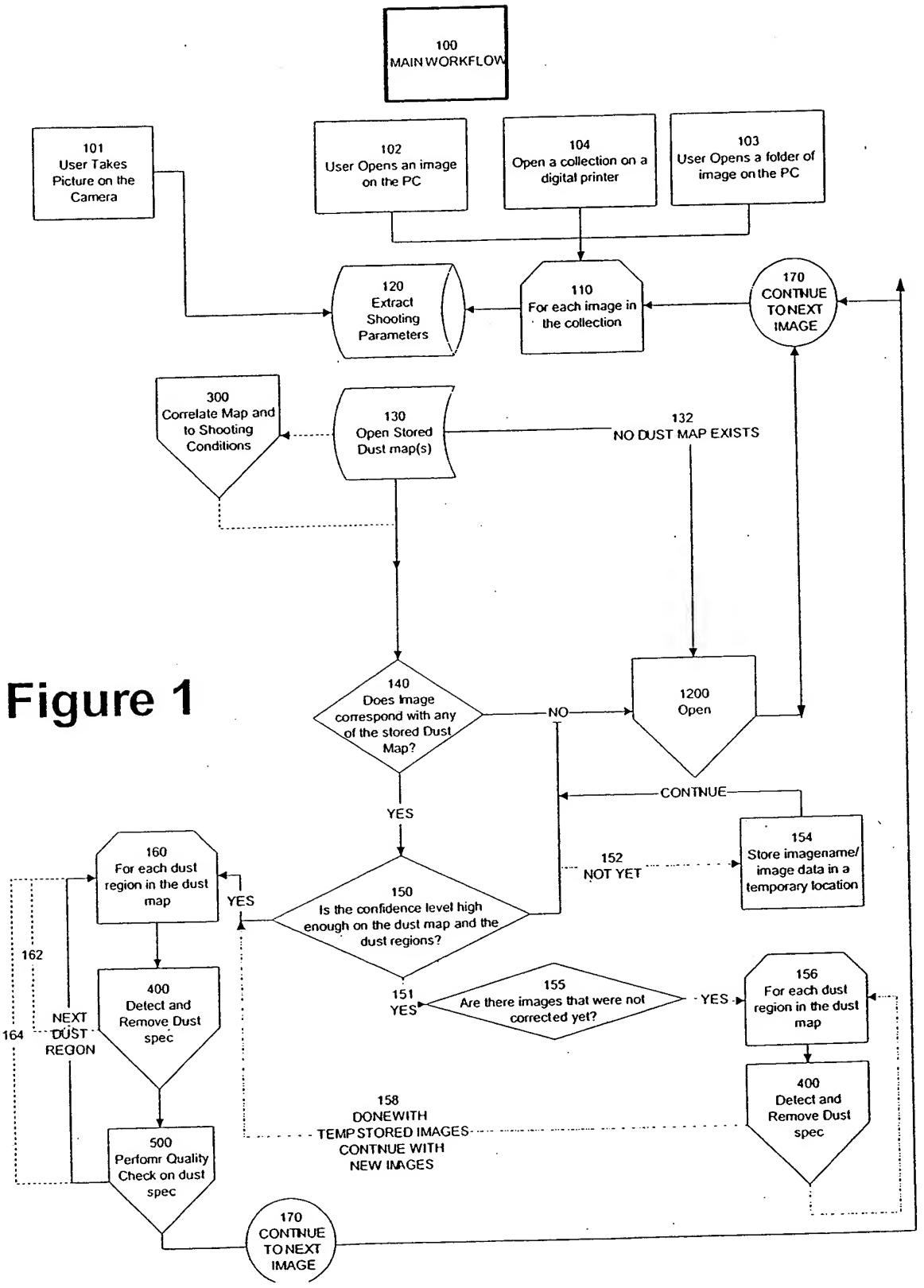
100
MAIN WORKFLOW
101
User Takes Picture on the Camera
102
User Opens an image on the PC
104
Open a collection on a digital printer
103
User Opens a folder of image on the PC
120
Extract Shooting Parameters
110
For each image in the collection
170
CONTINUE TO NEXT IMAGE
300
Correlate Map and to Shooting Conditions
130
Open Stored Dust map(s)
132
NO DUST MAP EXISTS
140
Does Image correspond with any of the stored Dust Map?
NO
1200
Open
CONTINUE
YES
160
For each dust region in the dust map
YES
150
Is the confidence level high enough on the dust map and the dust regions?
152
NOT YET
154
Store imagename/ image data in a temporary location
162
NEXT DUST REGION
164
400
Detect and Remove Dust spec
151
YES
155
Are there images that were not corrected yet?
YES
156
For each dust region in the dust map
400
Detect and Remove Dust spec
158
DONEWITH TEMPSTORED IMAGES CONTNUE WITH NEW IMAGES
500
Perfomr Quality Check on dust spec
170
CONTINUE TO NEXT IMAGE

Figure 1

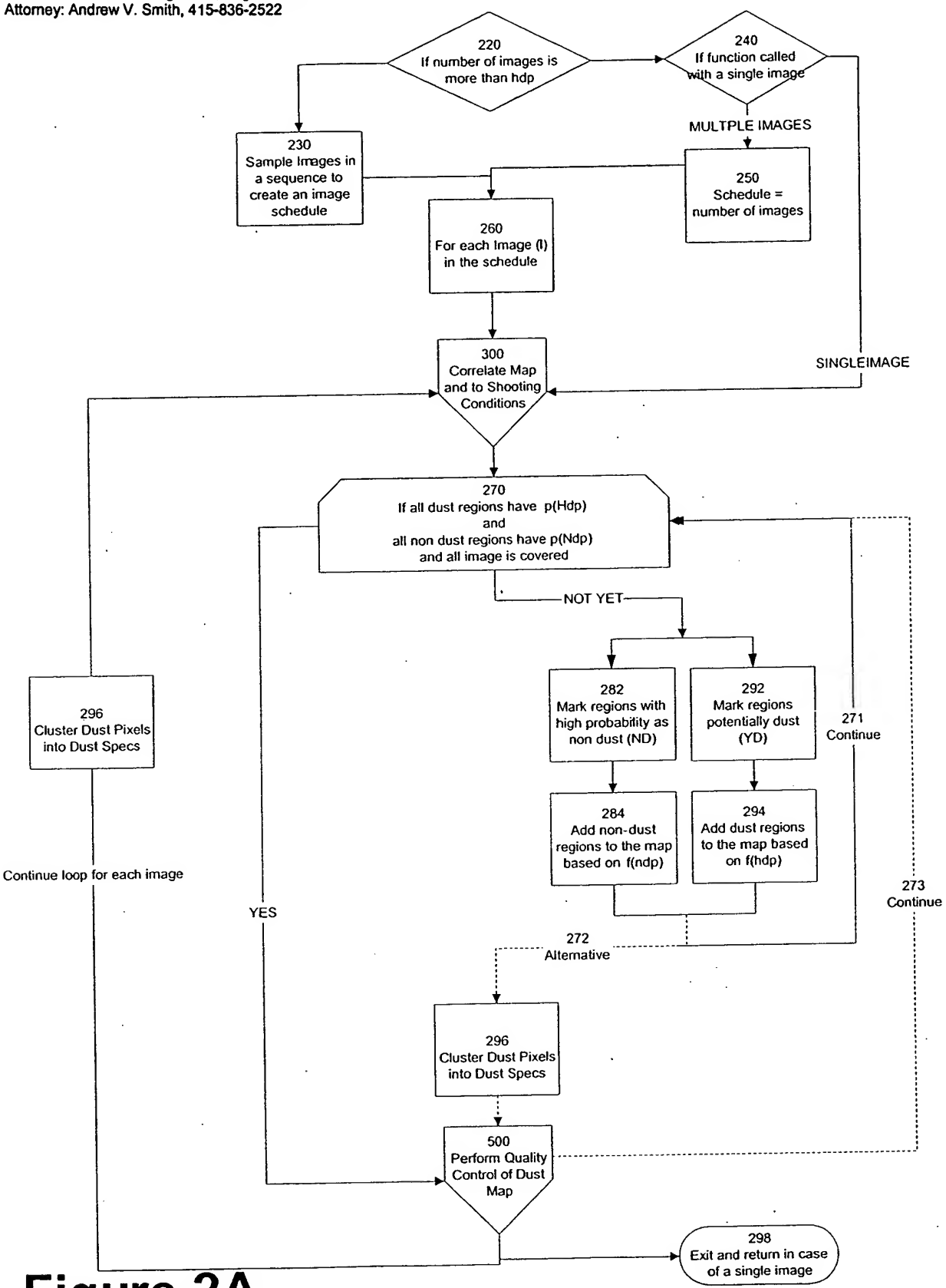
220
If number of images is more than hdp
240
If function called with a single image
MULTPLE IMAGES
230
Sample Images in a sequence to create an image schedule
250
Schedule = number of images
260
For each Image (I) in the schedule
300
Correlate Map and to Shooting Conditions
SINGLEIMAGE
270
If all dust regions have p(Hdp) and all non dust regions have p(Ndp) and all image is covered
NOT YET
282
Mark regions with high probability as non dust (ND)
292
Mark regions potentially dust (YD)
271
Continue
284
Add non-dust regions to the map based on f(ndp)
294
Add dust regions to the map based on f(hdp)
273
Continue
272
Alternative
296
Cluster Dust Pixels into Dust Specs
YES
296
Cluster Dust Pixels into Dust Specs
Continue loop for each image
500
Perform Quality Control of Dust Map
298
Exit and return in case of a single image

Figure 2A

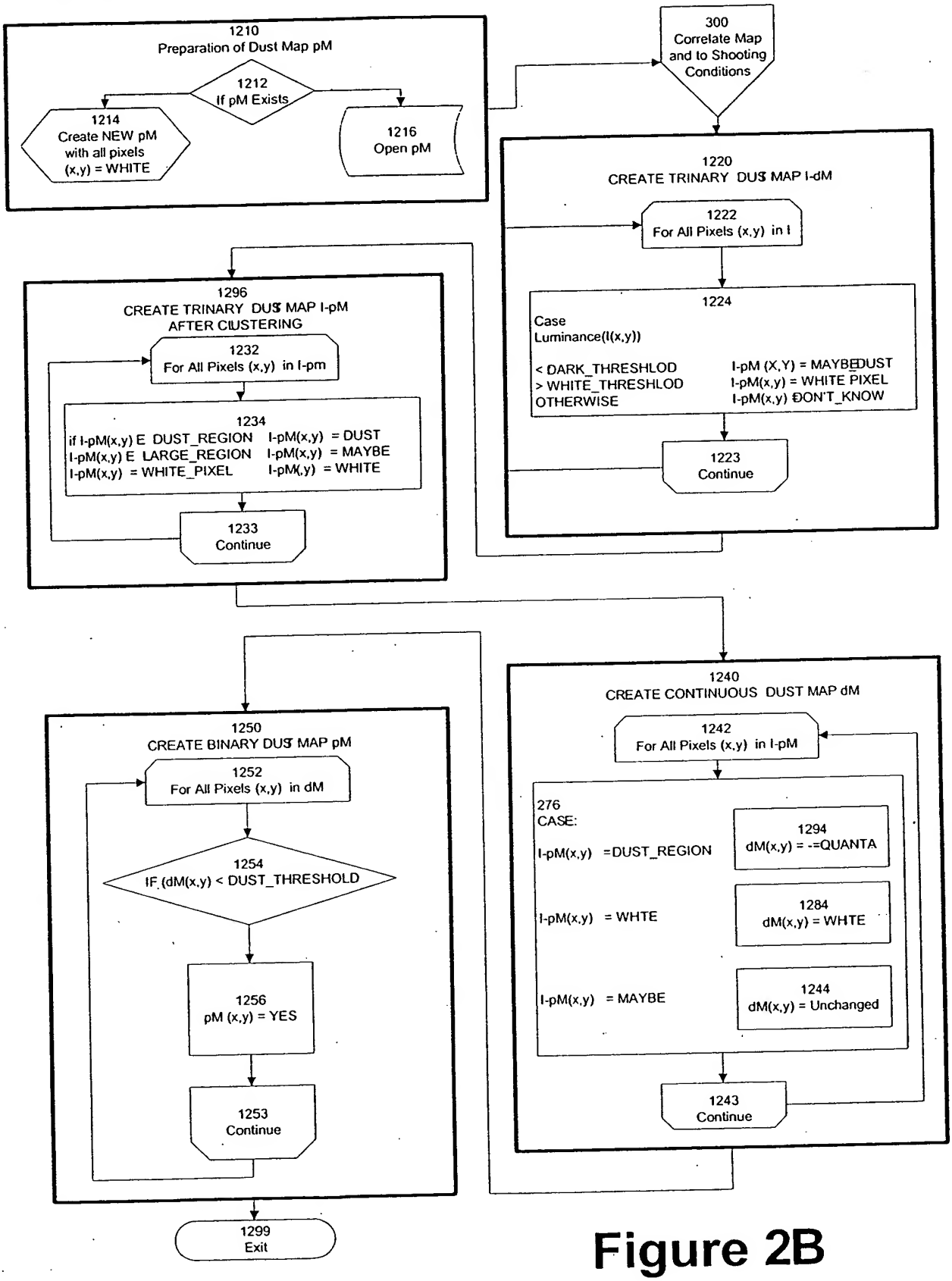
1210
Preparation of Dust Map pM
1212
If pM Exists
1214
Create NEW pM
with all pixels
(x,y) = WHITE
1216
Open pM
300
Correlate Map
and to Shooting
Conditions
1220
CREATE TRINARY DUST MAP I-dM
1222
For All Pixels (x,y) in I
1224
Case
Luminance(I(x,y))
< DARK_THRESHLOD
I-pM (X,Y) = MAYBE DUST
> WHITE_THRESHLOD
I-pM(x,y) = WHITE PIXEL
OTHERWISE
I-pM(x,y) DON'T_KNOW
1223
Continue
1296
CREATE TRINARY DUST MAP I-pM
AFTER CLUSTERING
1232
For All Pixels (x,y) in I-pm
1234
if I-pM(x,y) E DUST_REGION
I-pM(x,y) = DUST
I-pM(x,y) E LARGE_REGION
I-pM(x,y) = MAYBE
I-pM(x,y) = WHITE_PIXEL
I-pM(x,y) = WHITE
1233
Continue
1240
CREATE CONTINUOUS DUST MAP dM
1242
For All Pixels (x,y) in I-pM
276
CASE:
I-pM(x,y) =DUST_REGION
1294
dM(x,y) = -=QUANTA
I-pM(x,y) = WHTE
1284
dM(x,y) = WHTE
I-pM(x,y) = MAYBE
1244
dM(x,y) = Unchanged
1243
Continue
1250
CREATE BINARY DUST MAP pM
1252
For All Pixels (x,y) in dM
1254
IF (dM(x,y) < DUST_THRESHOLD
1256
pM (x,y) = YES
1253
Continue
1299
Exit

Figure 2B

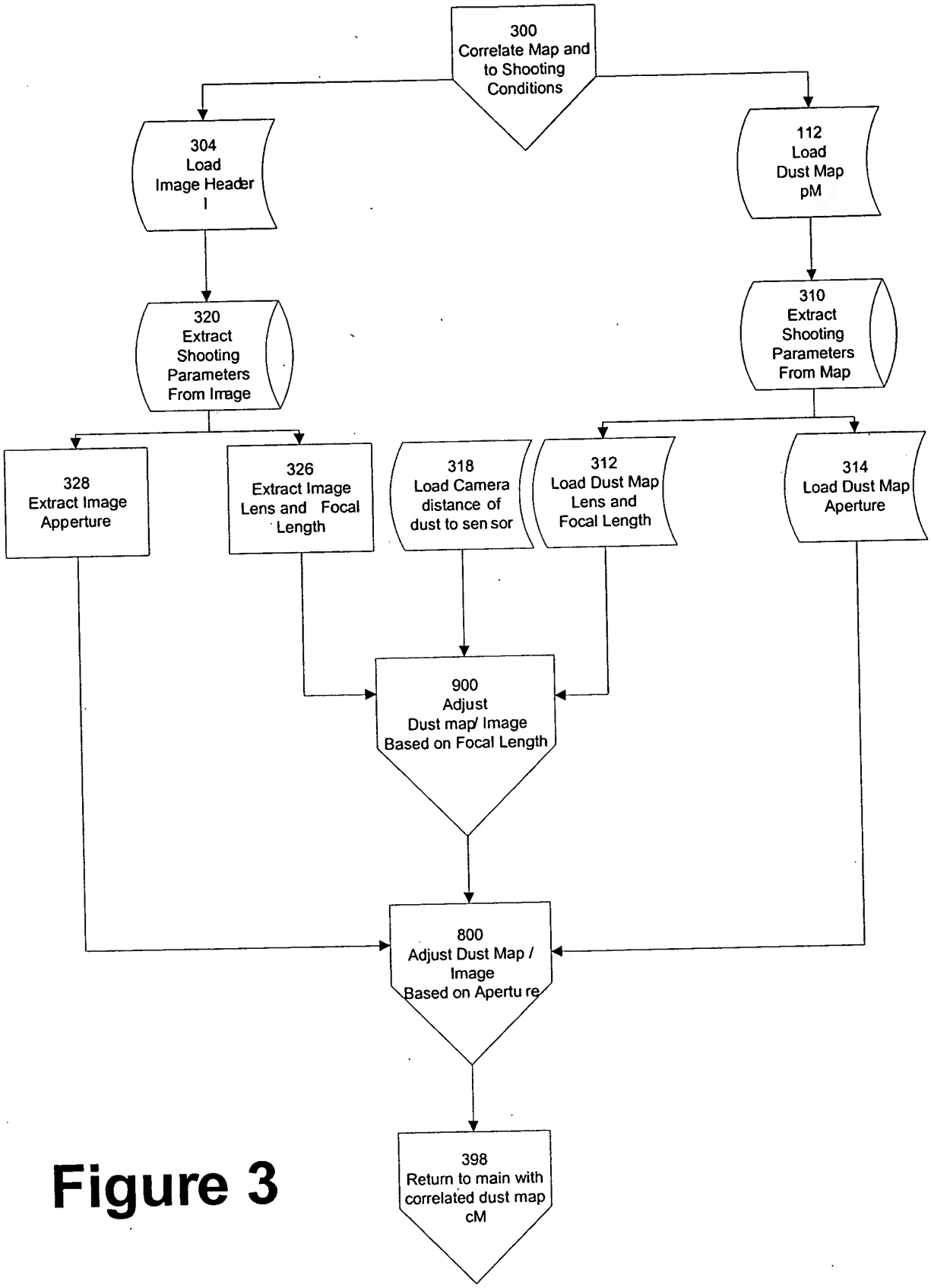
300
Correlate Map and to Shooting Conditions
304
Load Image Header I
112
Load Dust Map pM
320
Extract Shooting Parameters From Image
310
Extract Shooting Parameters From Map
328
Extract Image Apperture
326
Extract Image Lens and Focal Length
318
Load Camera distance of dust to sen sor
312
Load Dust Map Lens and Focal Length
314
Load Dust Map Aperture
900
Adjust Dust map/ Image Based on Focal Length
800
Adjust Dust Map / Image Based on Apertu re
398
Return to main with correlated dust map cM

Figure 3

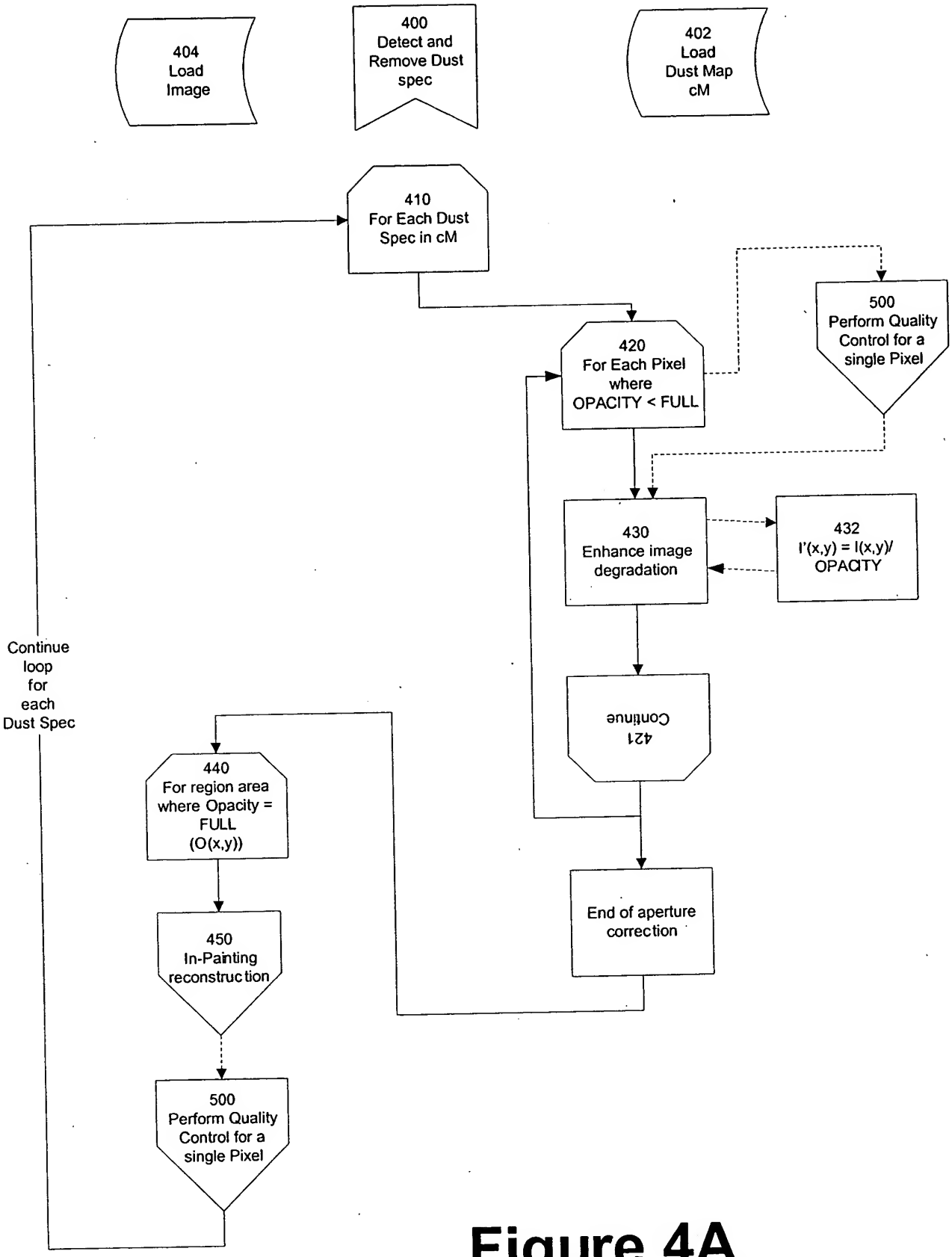
404
Load
Image
400
Detect and
Remove Dust
spec
402
Load
Dust Map
cM
410
For Each Dust
Spec in cM
420
For Each Pixel
where
OPACITY < FULL
500
Perform Quality
Control for a
single Pixel
430
Enhance image
degradation
432
I'(x,y) = I(x,y)/
OPACITY
421
Continue
440
For region area
where Opacity =
FULL
(O(x,y))
450
In-Painting
reconstruction
End of aperture
correction
500
Perform Quality
Control for a
single Pixel
Continue
loop
for
each
Dust Spec

Figure 4A

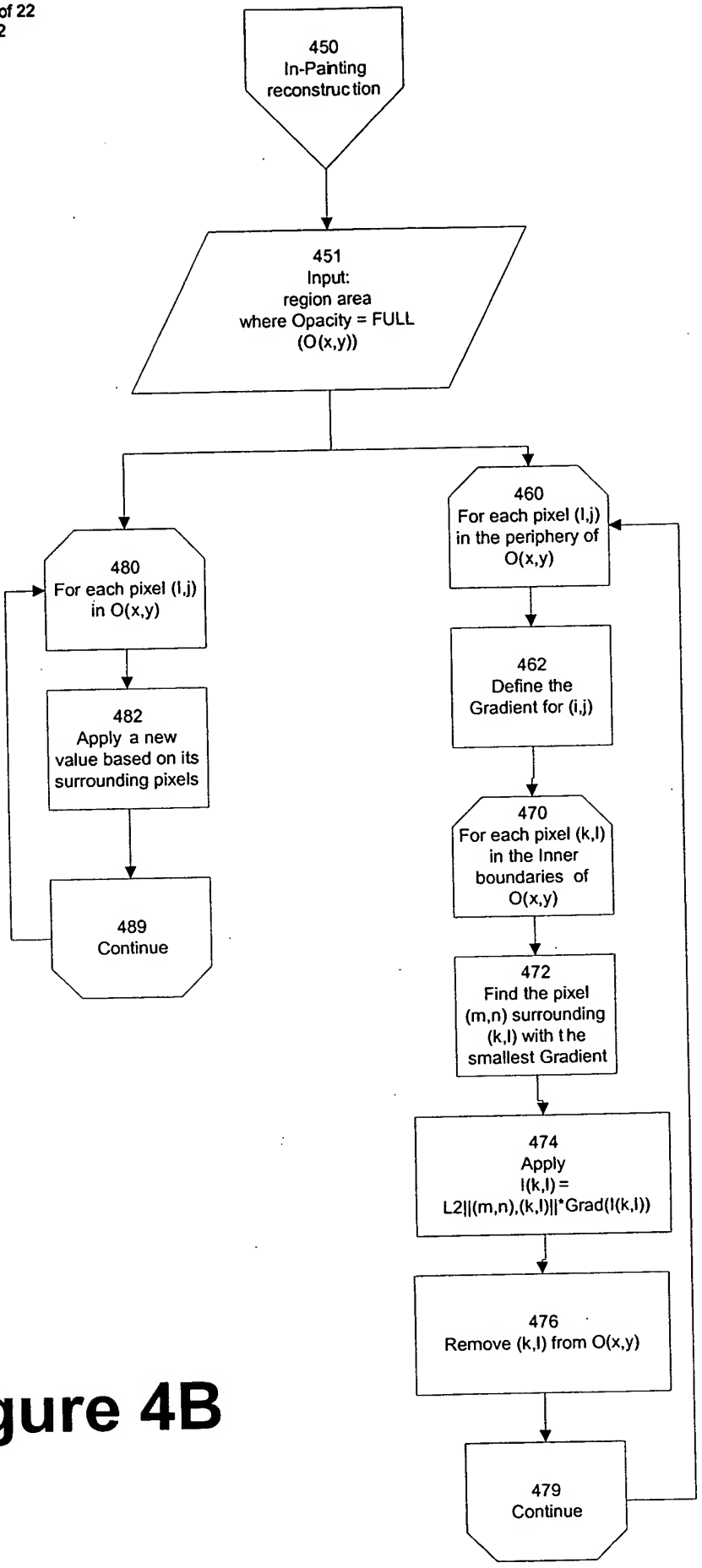
450
In-Painting reconstruction
451
Input:
region area
where Opacity = FULL
(O(x,y))
460
For each pixel (I,j) in the periphery of O(x,y)
462
Define the Gradient for (i,j)
470
For each pixel (k,l) in the Inner boundaries of O(x,y)
472
Find the pixel (m,n) surrounding (k,l) with the smallest Gradient
474
Apply
I(k,l) =
L2||(m,n),(k,l)||*Grad(I(k,l))
476
Remove (k,l) from O(x,y)
479
Continue
480
For each pixel (I,j) in O(x,y)
482
Apply a new value based on its surrounding pixels
489
Continue

Figure 4B

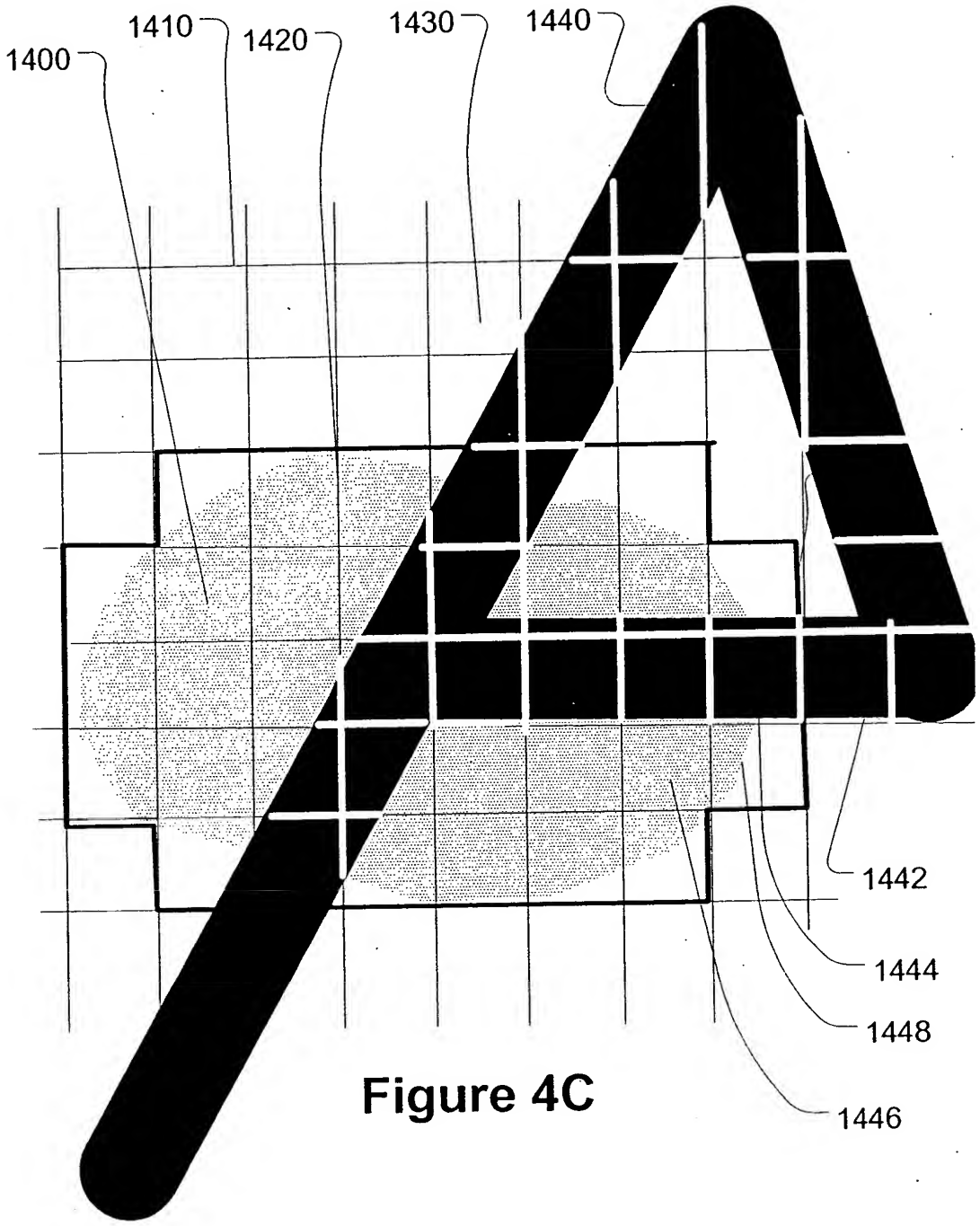

Figure 4C

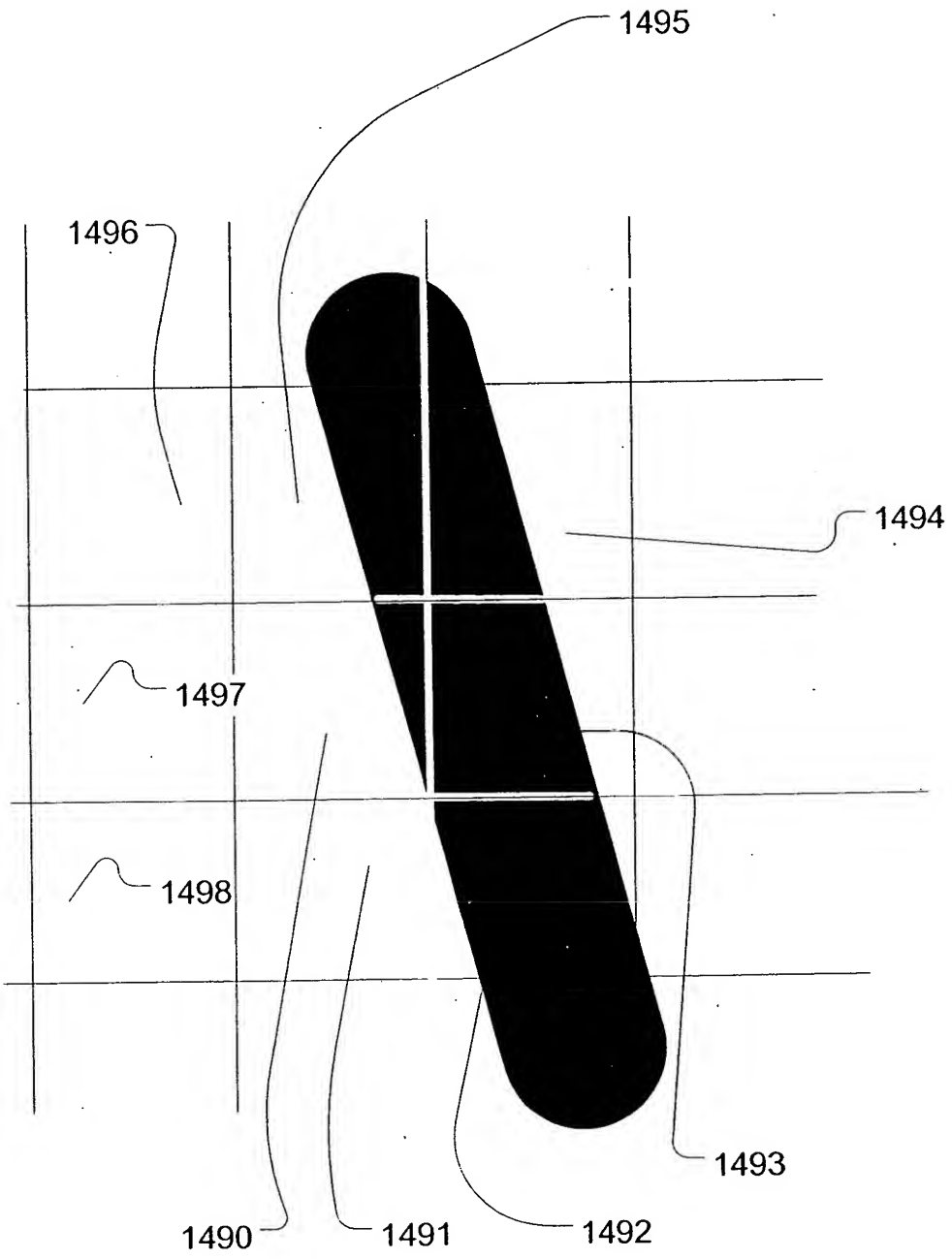

Figure 4D

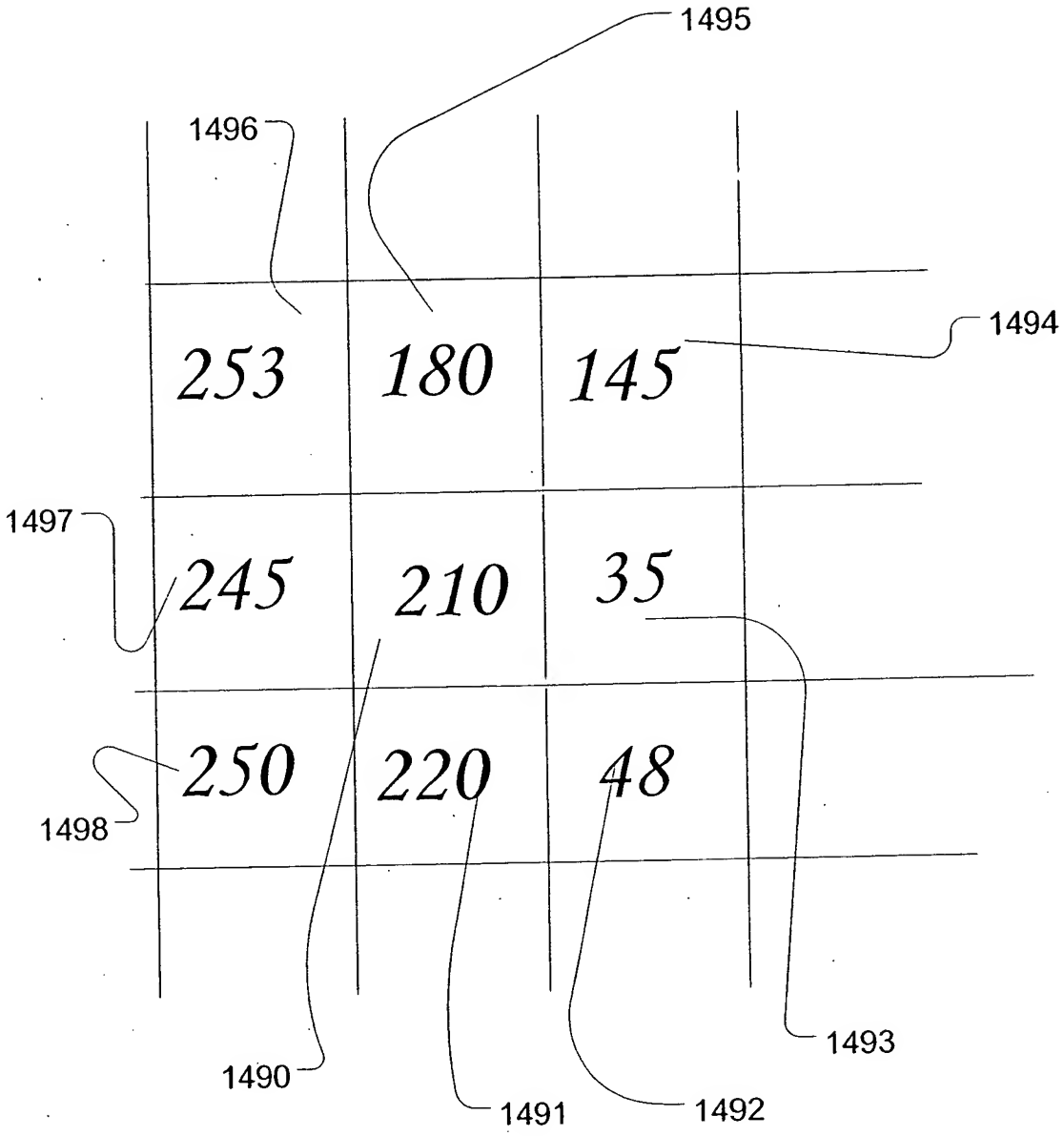
1495
1496
1494
253
180
145
1497
245
210
35
250
220
48
1498
1493
1490
1491
1492

Figure 4E

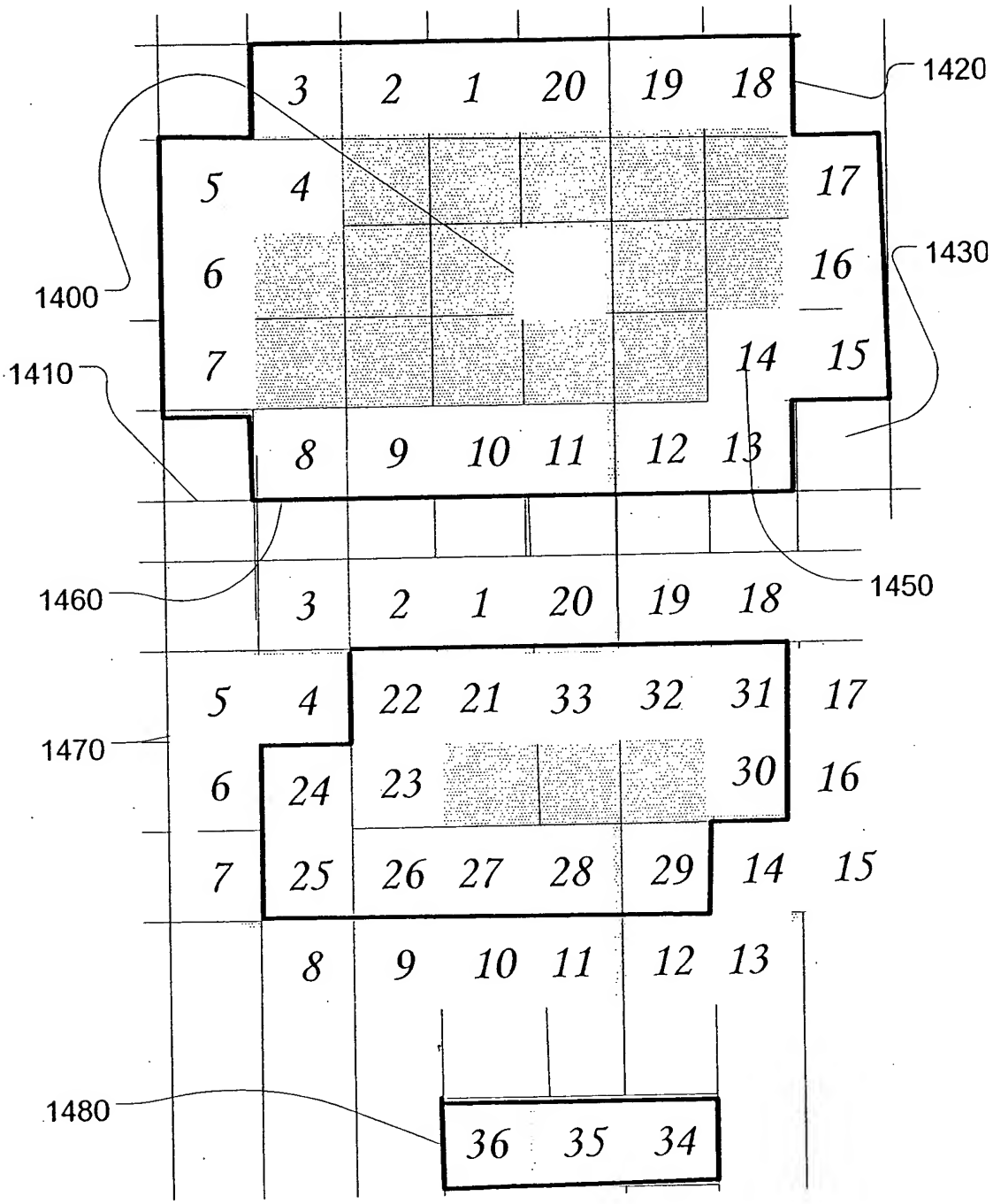
1400
1410
1420
1430
1450
1460
1470
1480
3 2 1 20 19 18
5 4 17
6 16
7 14 15
8 9 10 11 12 13
3 2 1 20 19 18
5 4 22 21 33 32 31 17
6 24 23 30 16
7 25 26 27 28 29 14 15
8 9 10 11 12 13
36 35 34

Figure 4F

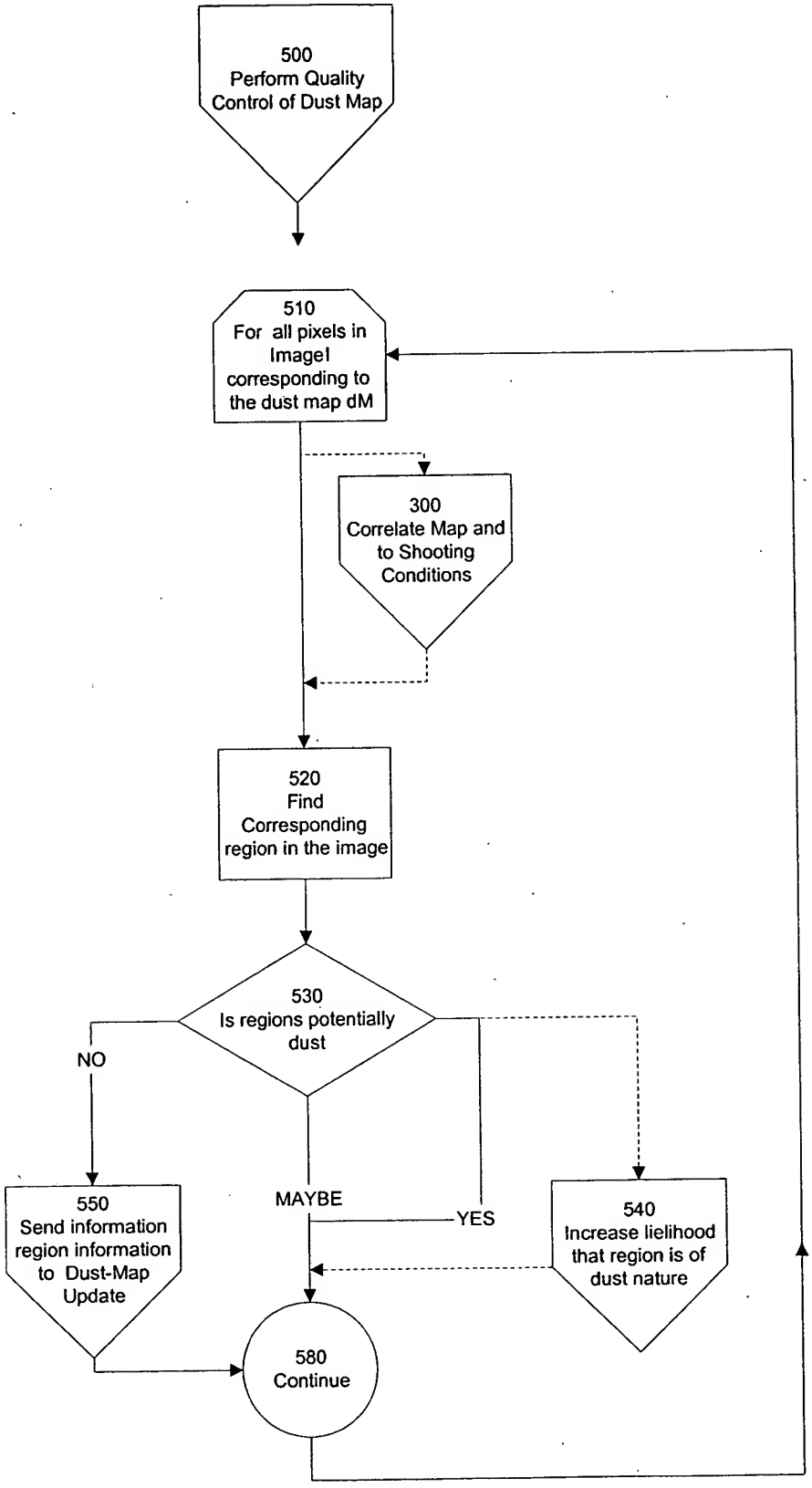
500
Perform Quality Control of Dust Map
510
For all pixels in Image1 corresponding to the dust map dM
300
Correlate Map and to Shooting Conditions
520
Find Corresponding region in the image
530
Is regions potentially dust
NO
MAYBE
YES
550
Send information region information to Dust-Map Update
540
Increase lielihood that region is of dust nature
580
Continue

Figure 5

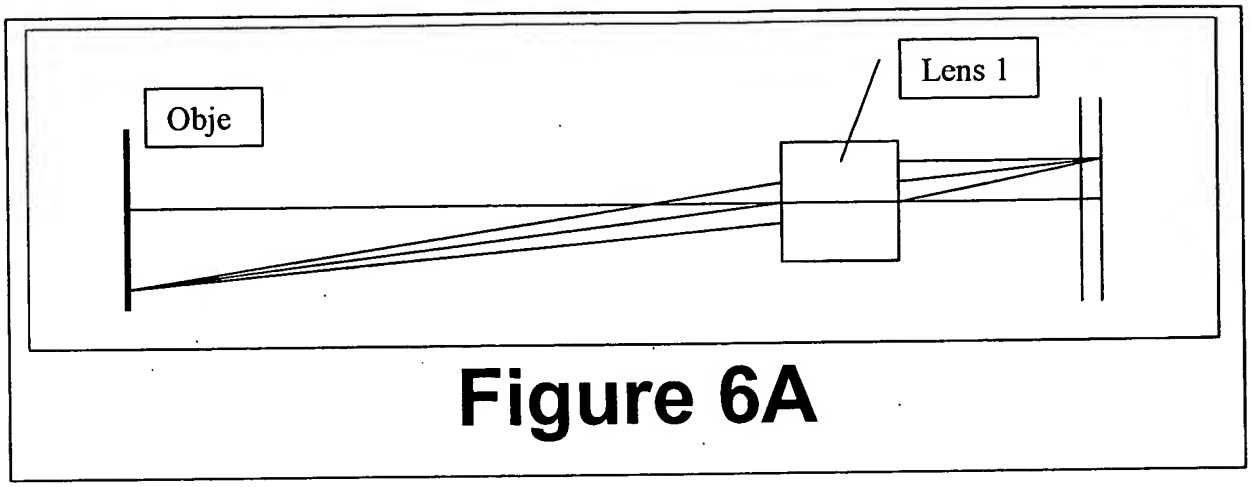

Figure 6A

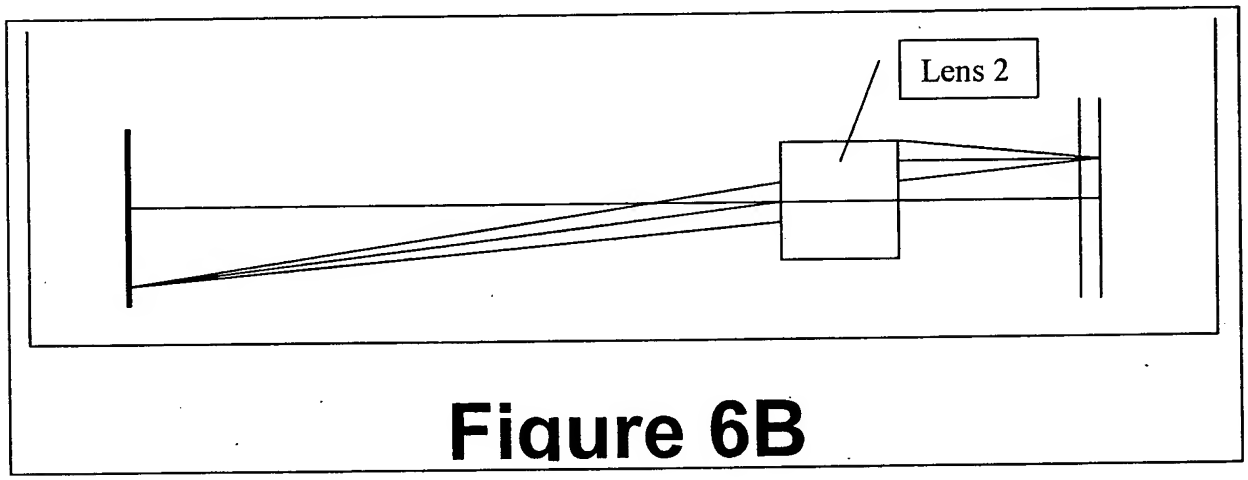

Figure 6B

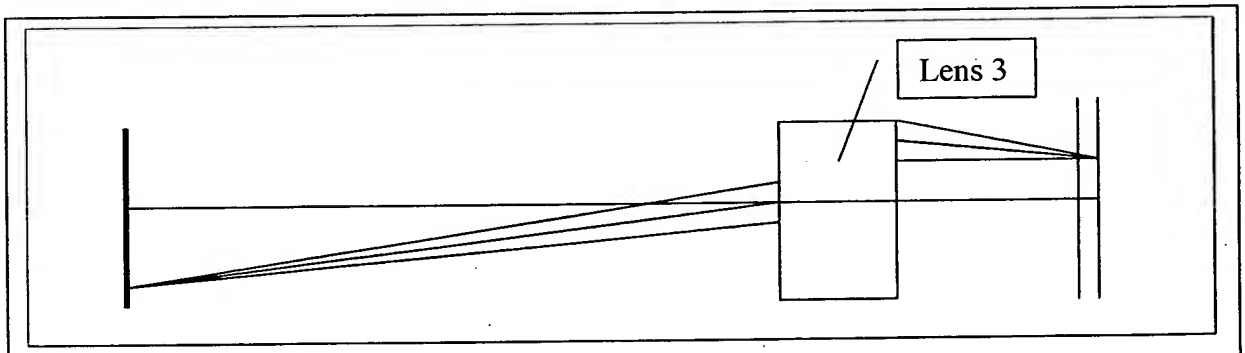

Figure 6C

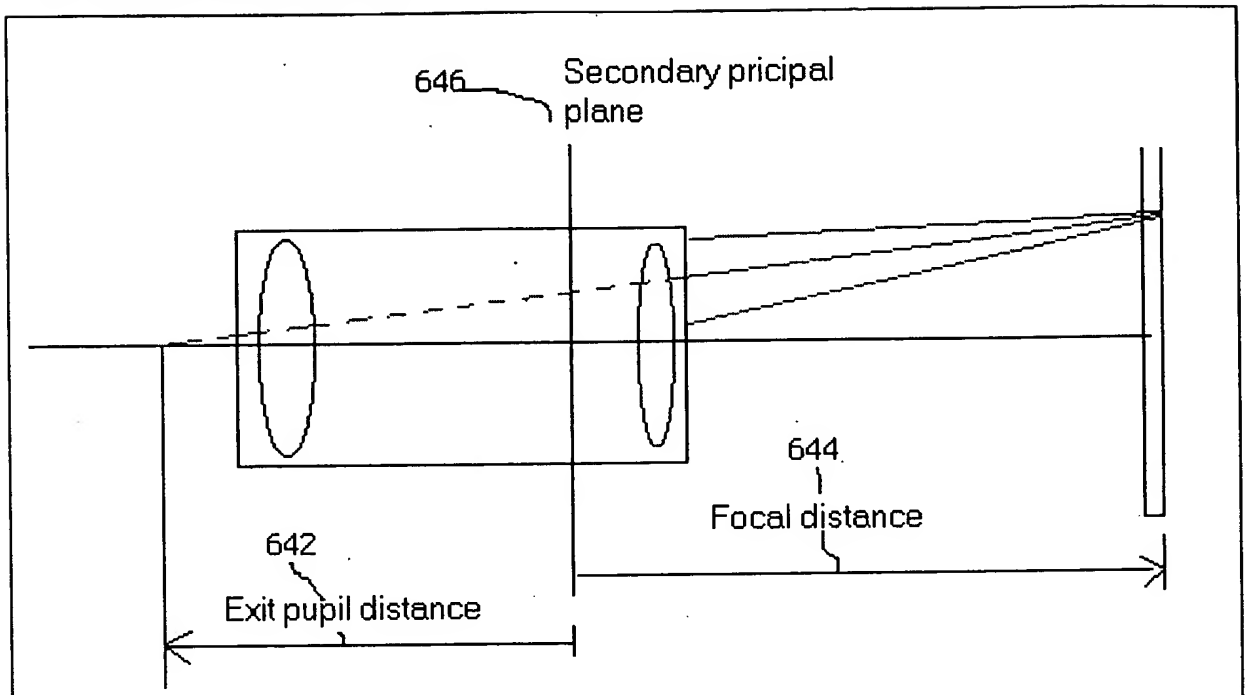

Figure 6D

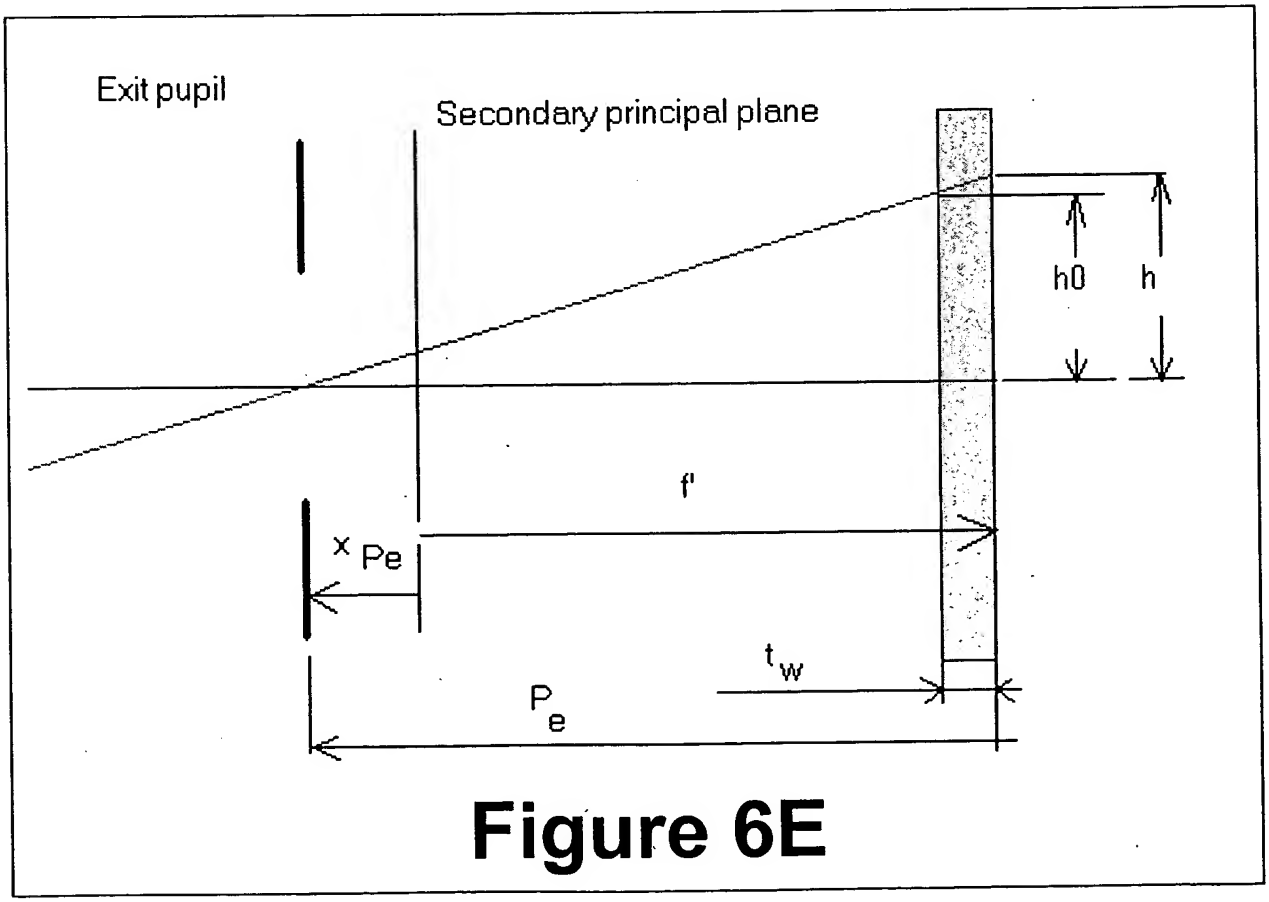

Figure 6E

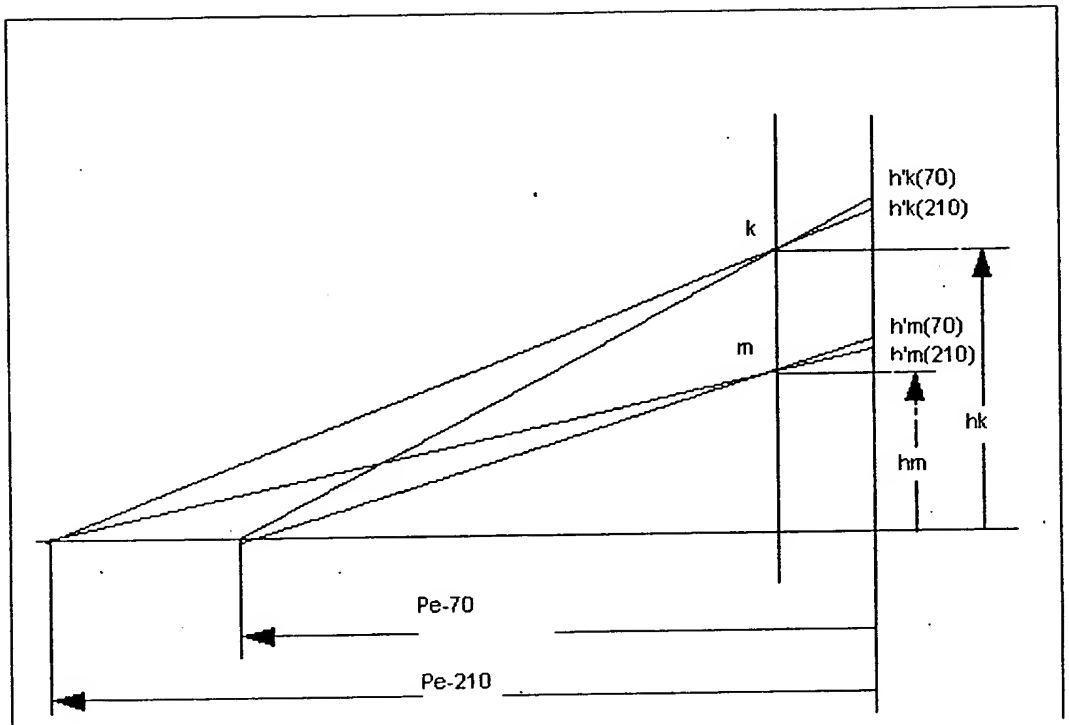

Figure 6F

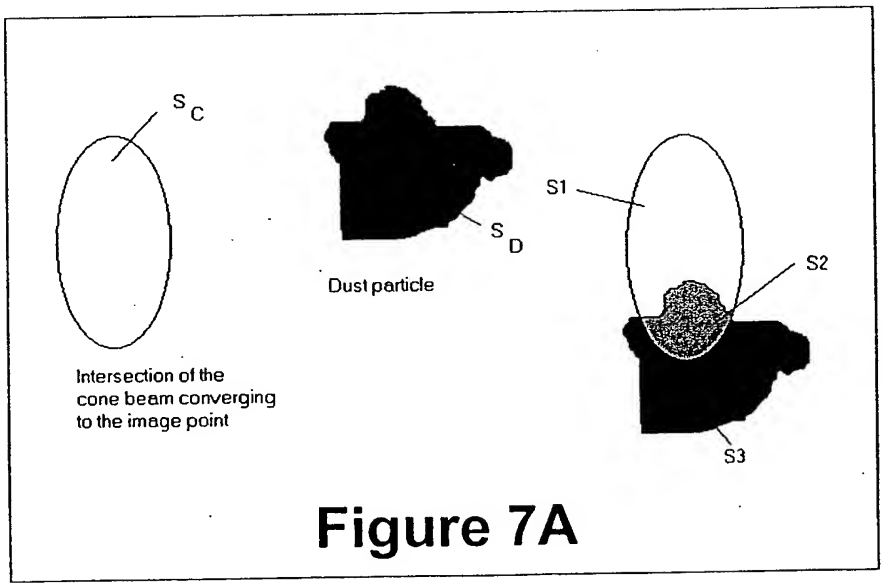

Figure 7A

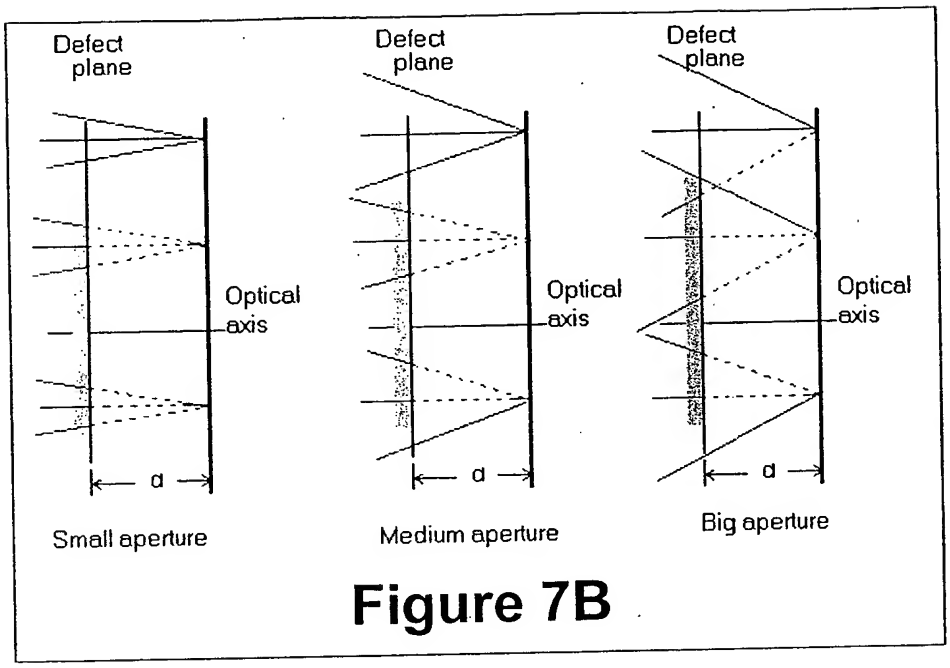

Figure 7B

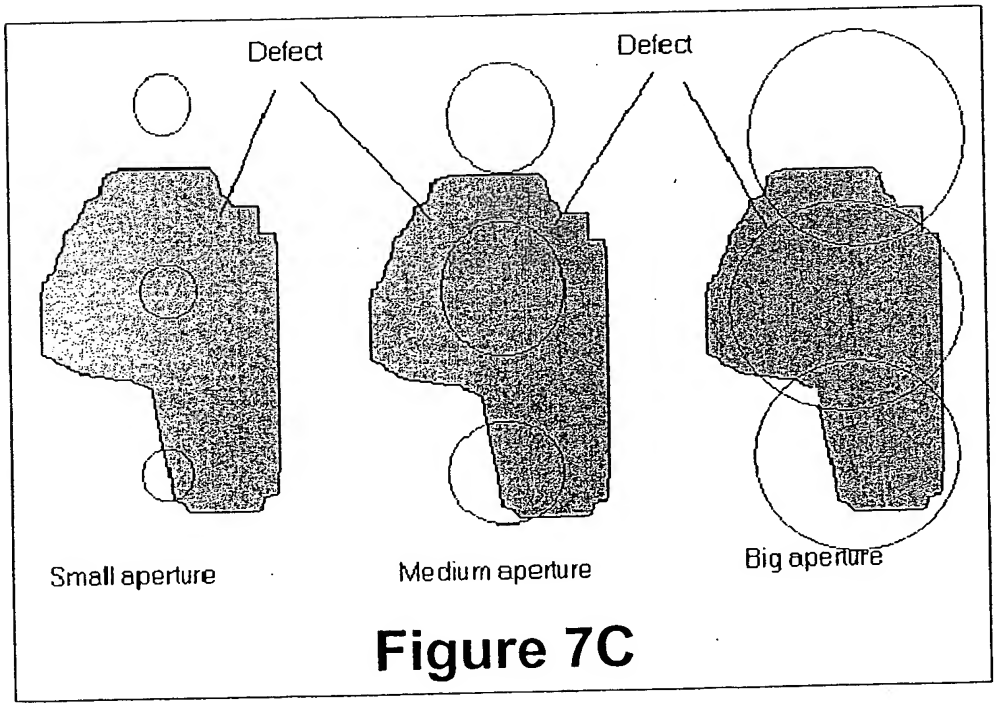

Figure 7C

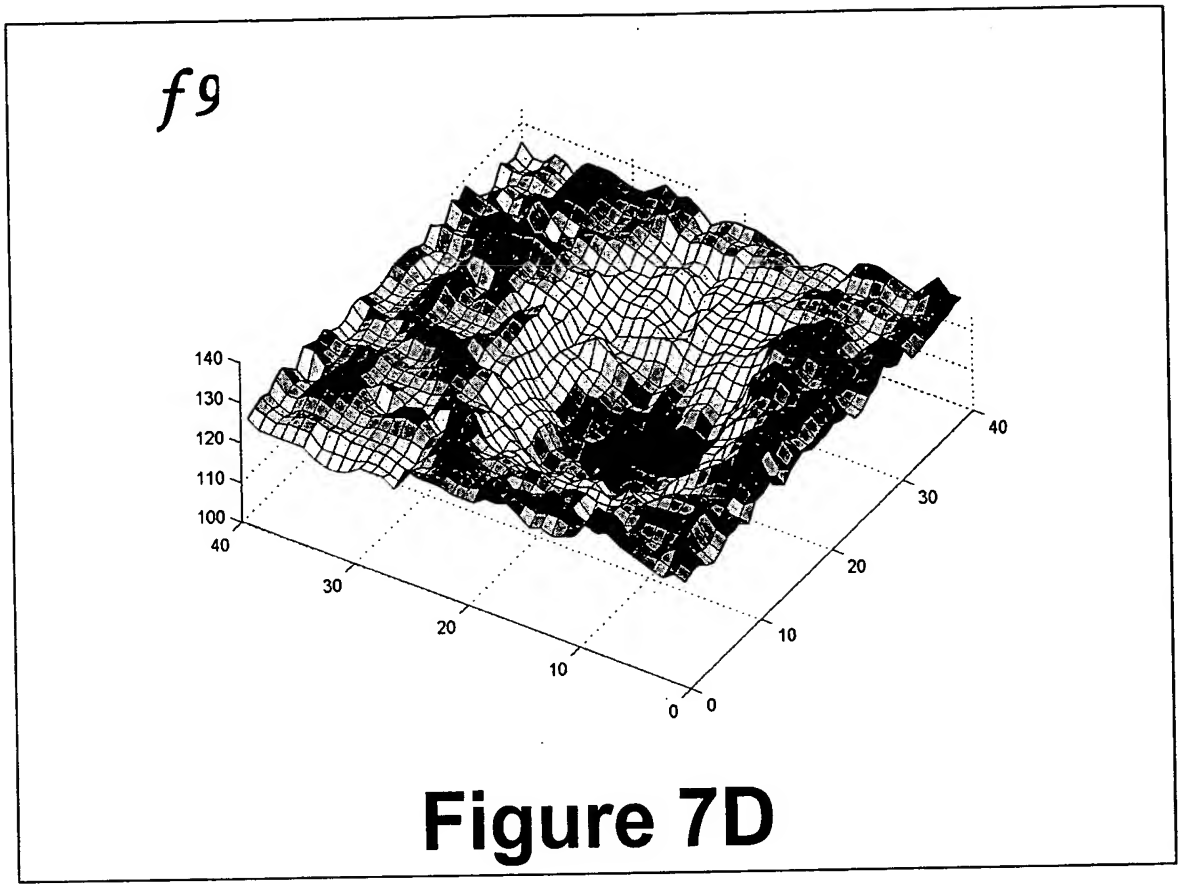

Figure 7D

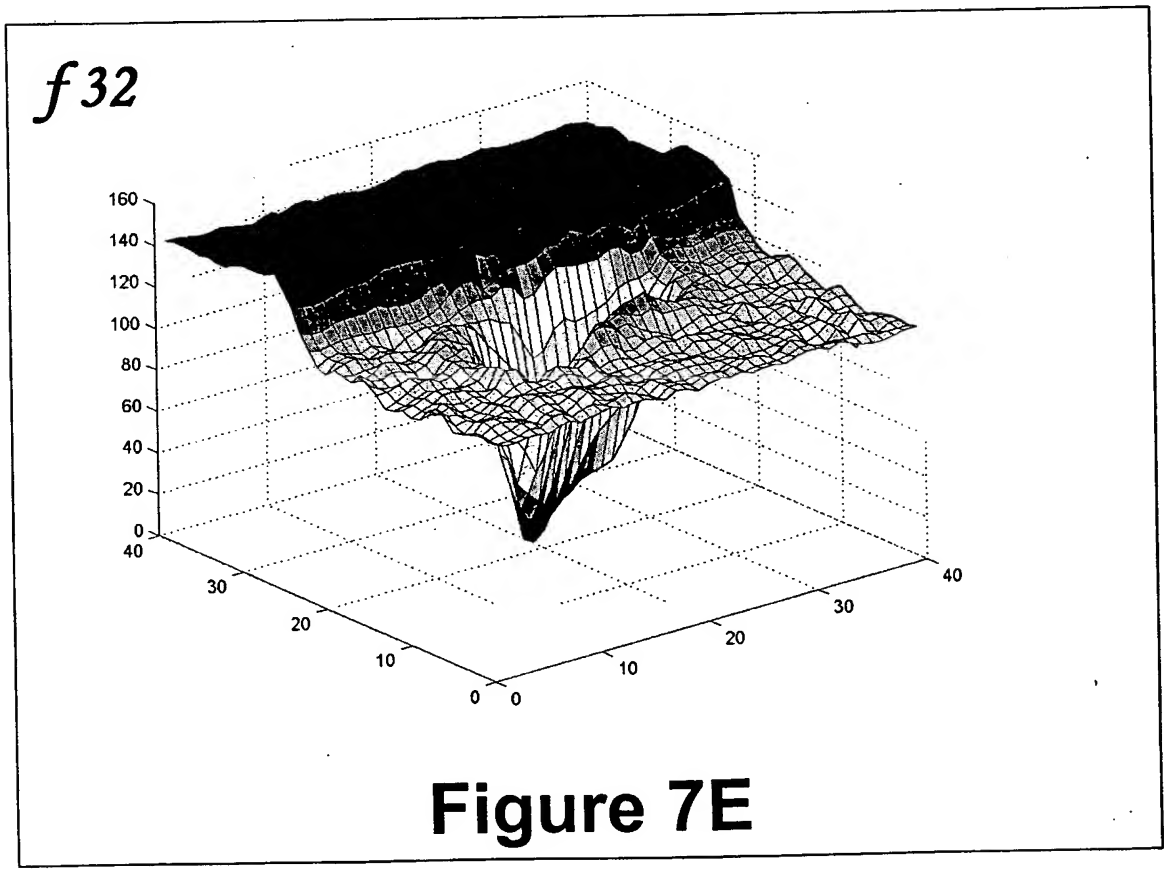

Figure 7E

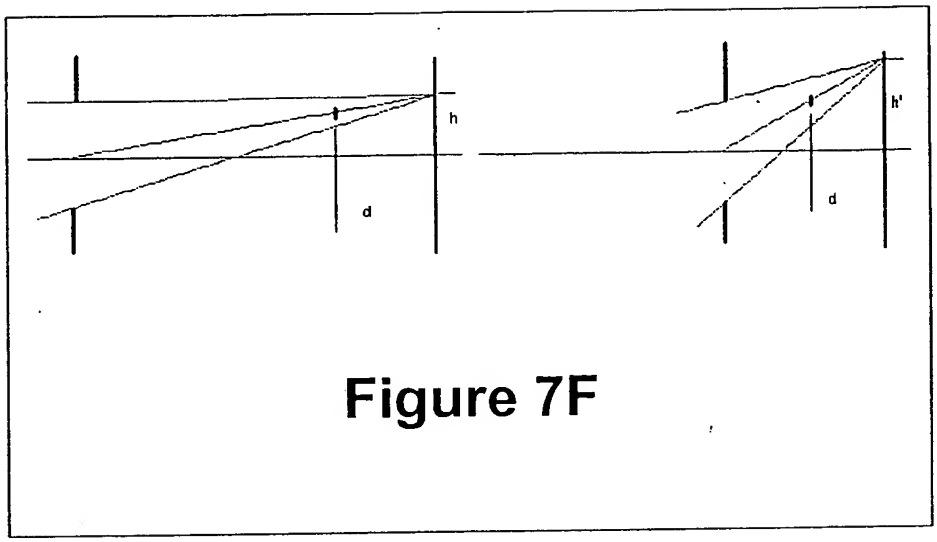

Figure 7F

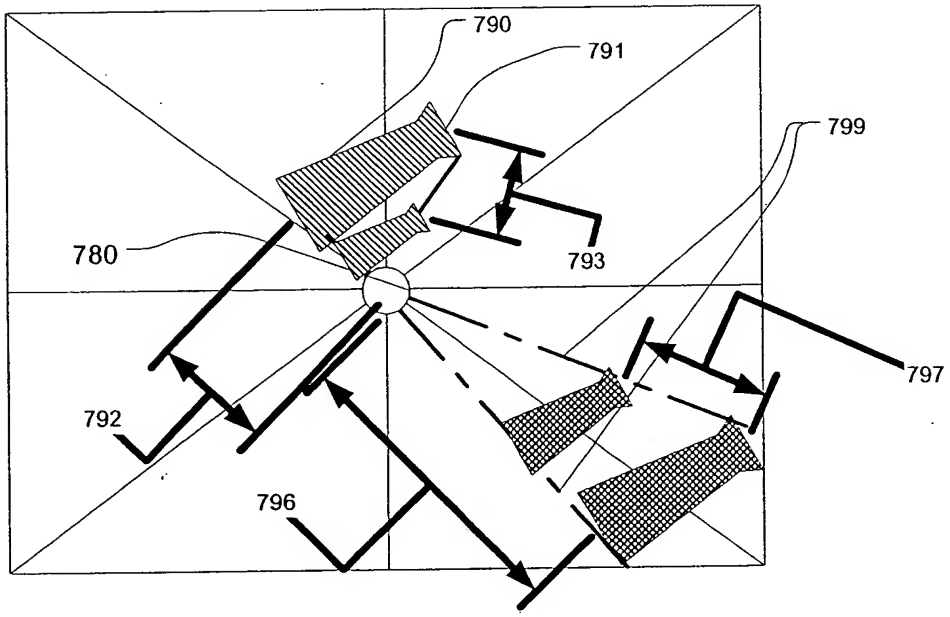

Figure 7G

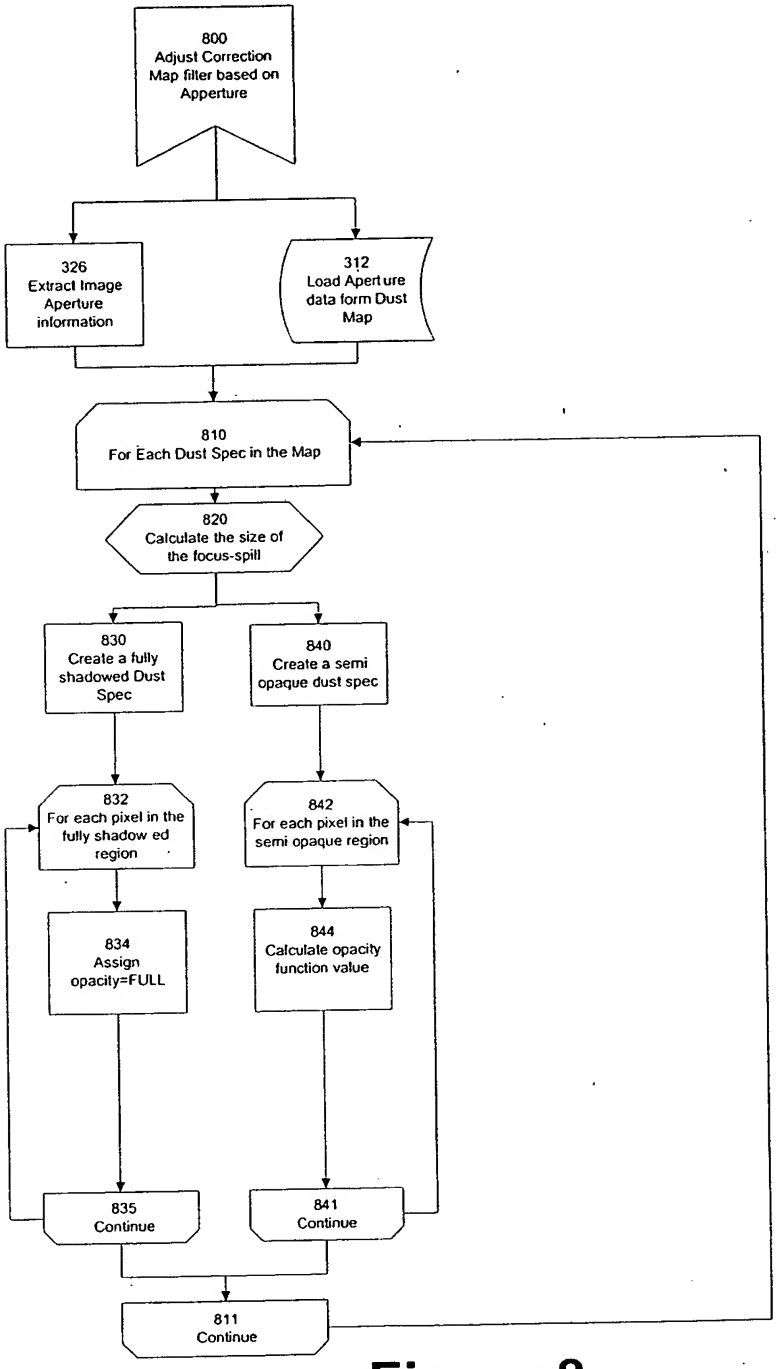
800
Adjust Correction Map filter based on Apperture
326
Extract Image Aperture information
312
Load Aperture data form Dust Map
810
For Each Dust Spec in the Map
820
Calculate the size of the focus-spill
830
Create a fully shadowed Dust Spec
840
Create a semi opaque dust spec
832
For each pixel in the fully shadow ed region
842
For each pixel in the semi opaque region
834
Assign opacity=FULL
844
Calculate opacity function value
835
Continue
841
Continue
811
Continue

Figure 8

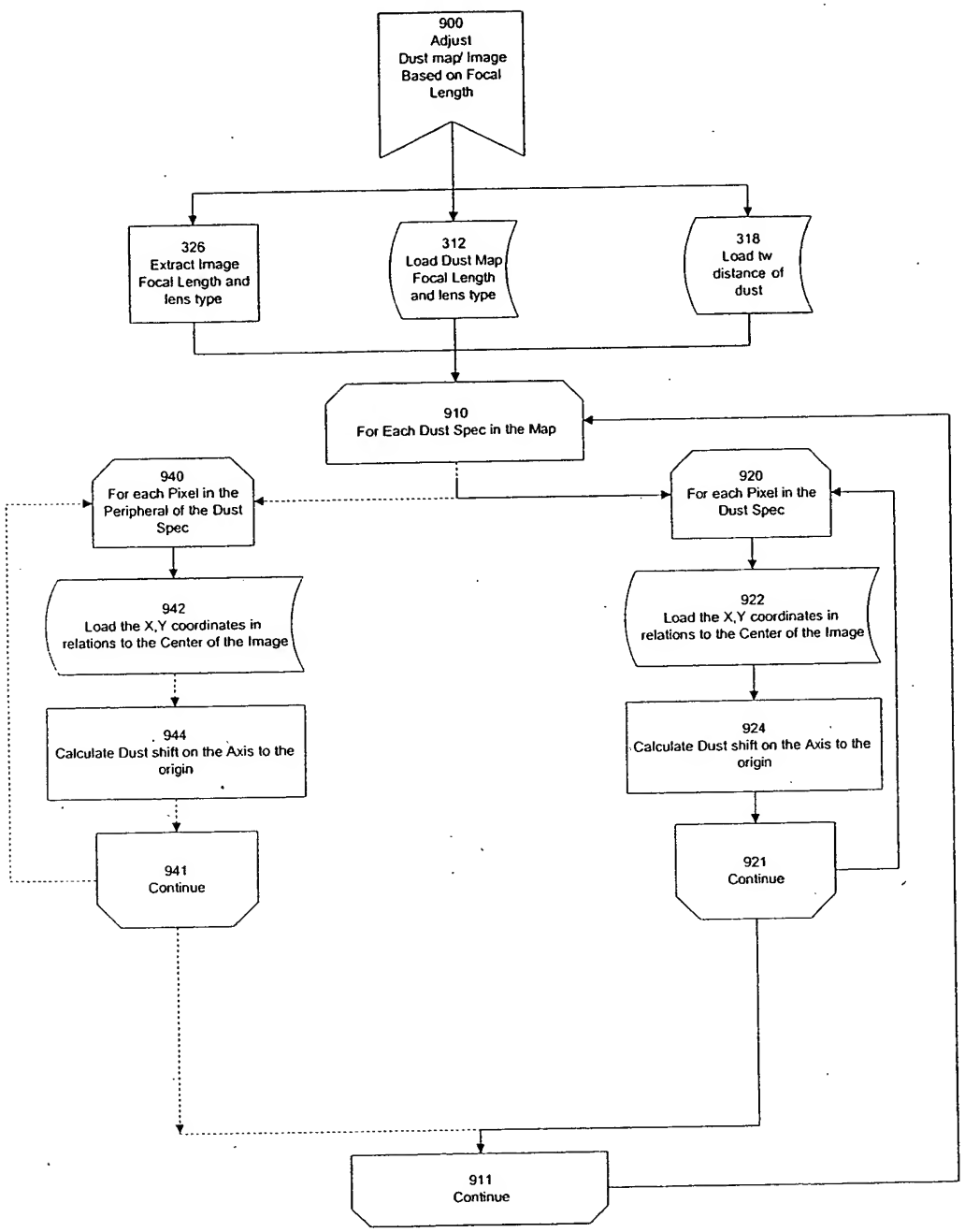
900
Adjust
Dust map/ Image
Based on Focal
Length
326
Extract Image
Focal Length and
lens type
312
Load Dust Map
Focal Length
and lens type
318
Load tw
distance of
dust
910
For Each Dust Spec in the Map
940
For each Pixel in the
Peripheral of the Dust
Spec
920
For each Pixel in the
Dust Spec
942
Load the X,Y coordinates in
relations to the Center of the Image
922
Load the X,Y coordinates in
relations to the Center of the Image
944
Calculate Dust shift on the Axis to the
origin
924
Calculate Dust shift on the Axis to the
origin
941
Continue
921
Continue
911
Continue

Figure 9

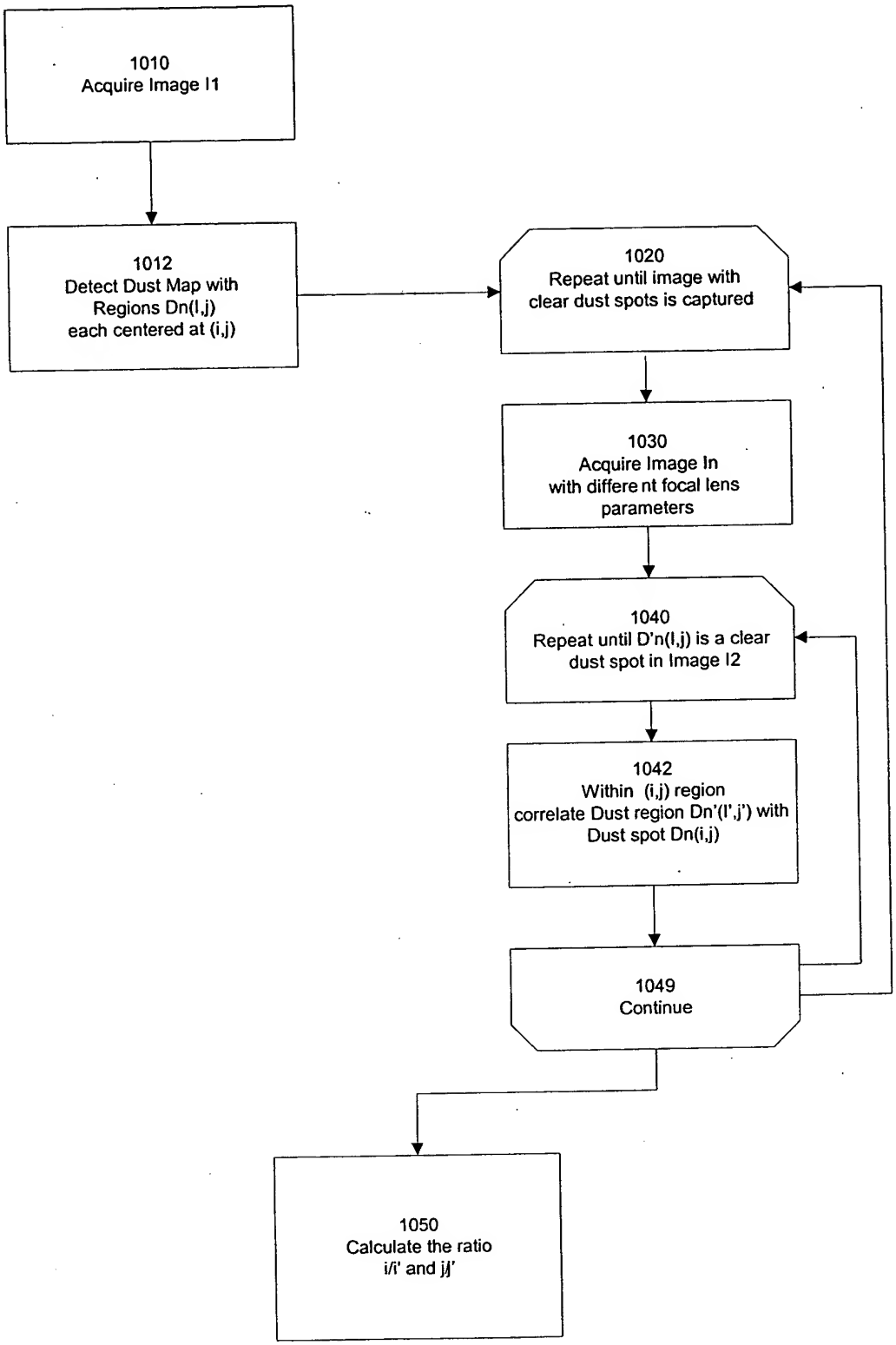
1010
Acquire Image I1
1012
Detect Dust Map with Regions Dn(I,j) each centered at (i,j)
1020
Repeat until image with clear dust spots is captured
1030
Acquire Image In with differe nt focal lens parameters
1040
Repeat until D'n(I,j) is a clear dust spot in Image I2
1042
Within (i,j) region correlate Dust region Dn'(I',j') with Dust spot Dn(i,j)
1049
Continue
1050
Calculate the ratio i/i' and j/j'

Figure 10

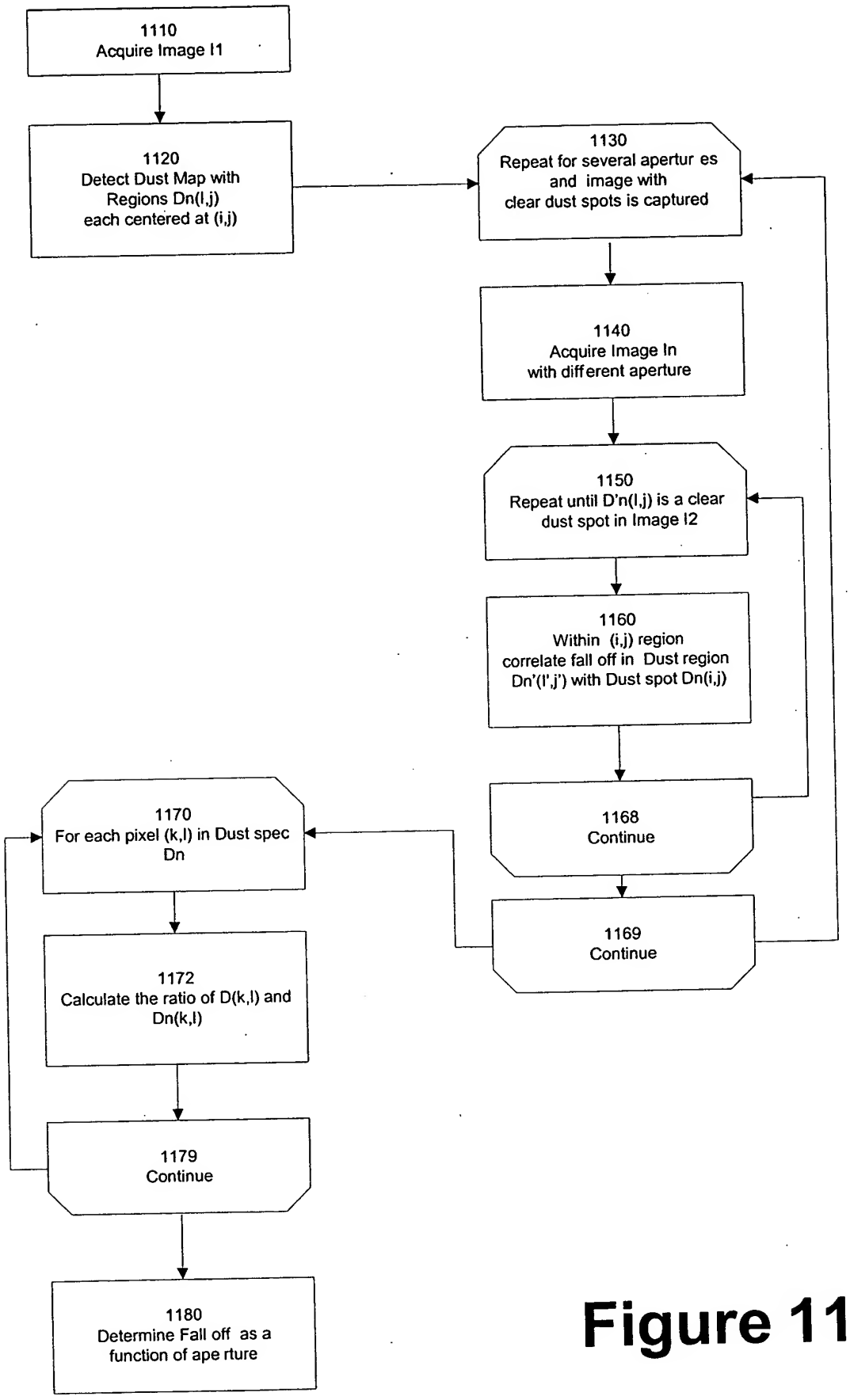
1110
Acquire Image I1
1120
Detect Dust Map with Regions Dn(I,j) each centered at (i,j)
1130
Repeat for several apertur es and image with clear dust spots is captured
1140
Acquire Image In with different aperture
1150
Repeat until D'n(I,j) is a clear dust spot in Image I2
1160
Within (i,j) region correlate fall off in Dust region Dn'(I',j') with Dust spot Dn(i,j)
1168
Continue
1169
Continue
1170
For each pixel (k,l) in Dust spec Dn
1172
Calculate the ratio of D(k,l) and Dn(k,l)
1179
Continue
1180
Determine Fall off as a function of ape rture

Figure 11

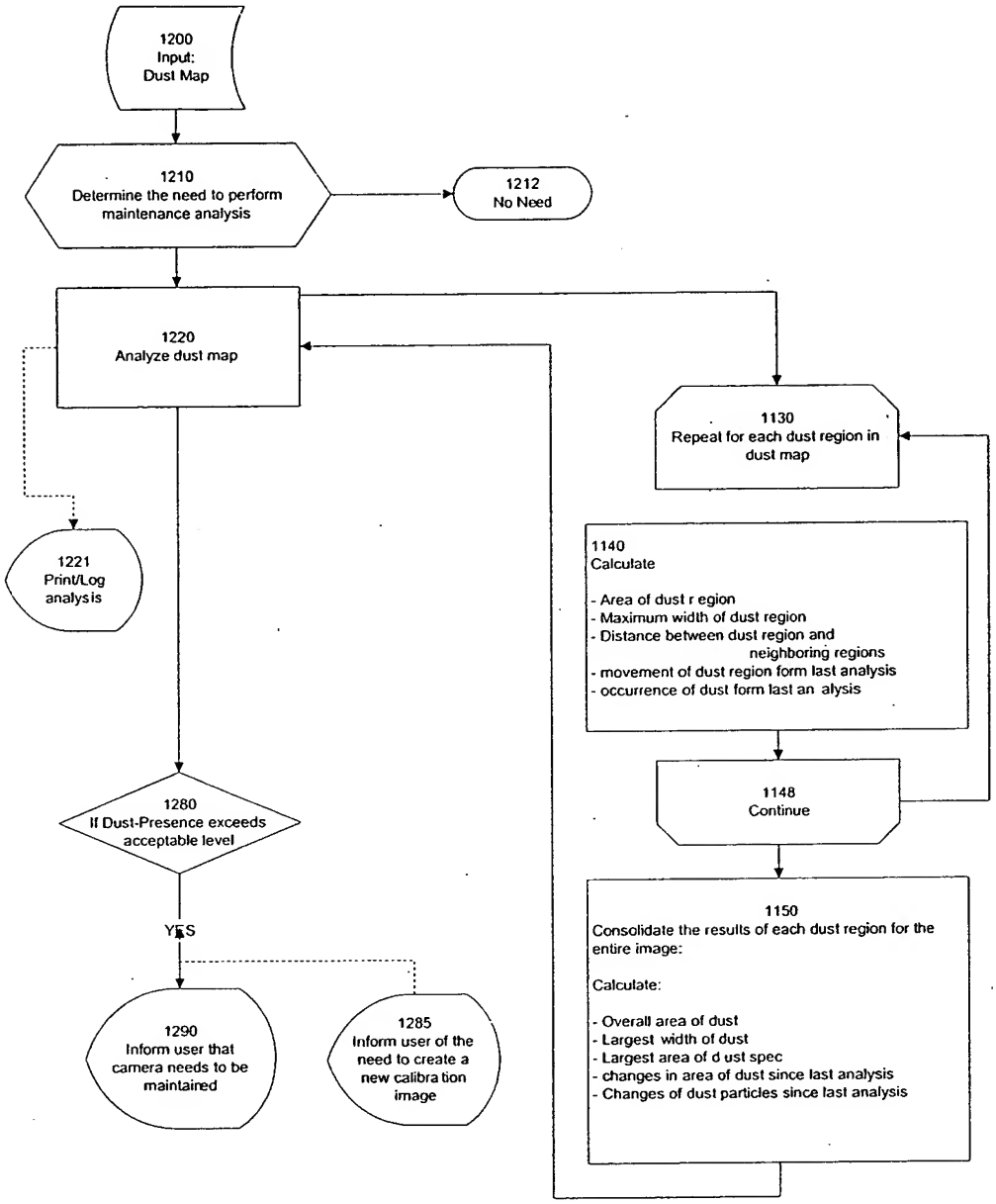
1200
Input:
Dust Map
1210
Determine the need to perform maintenance analysis
1212
No Need
1220
Analyze dust map
1221
Print/Log analysis
1280
If Dust-Presence exceeds acceptable level
YES
1290
Inform user that camera needs to be maintained
1285
Inform user of the need to create a new calibration image
1130
Repeat for each dust region in dust map
1140
Calculate
- Area of dust region
- Maximum width of dust region
- Distance between dust region and neighboring regions
- movement of dust region form last analysis
- occurrence of dust form last analysis
1148
Continue
1150
Consolidate the results of each dust region for the entire image:
Calculate:
- Overall area of dust
- Largest width of dust
- Largest area of dust spec
- changes in area of dust since last analysis
- Changes of dust particles since last analysis

Figure 12